Lead Toxicity and Children

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Disclaimers

All opinions expressed are those of the presenter and have not been reviewed or endorsed by any sponsoring organization.

I have served as an expert witness in lead toxicity litigation in multiple cases, all of which concluded more than 3 years ago.

Presentation Outline

- Lead effects on people
- Lead sources in the built environment and outdoors
- Measuring for lead
- Possible steps to reduce lead effects
- Risk communication is essential
- Questions

Pediatric Environmental Health

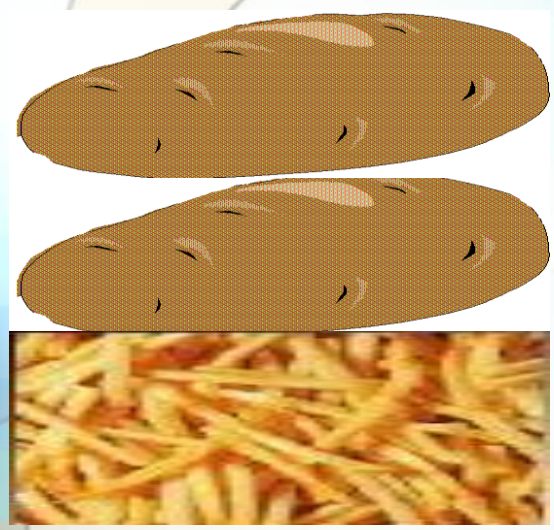
- Children are not just little adults
- Children's maturity changes with age, just as behavior and other features of childhood

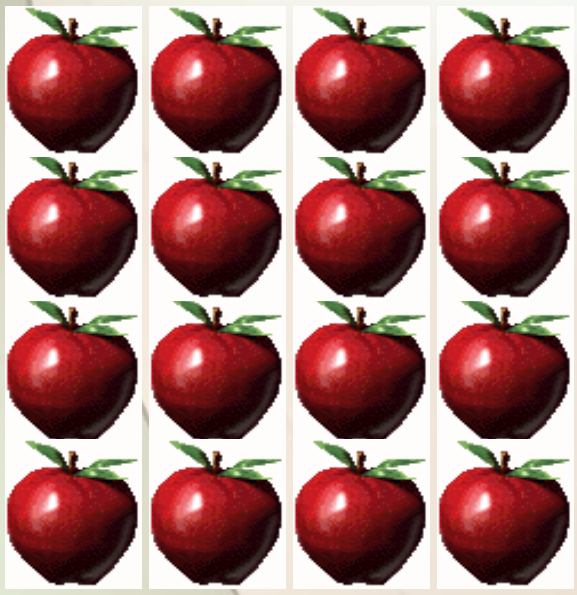
Differences in the physical environment

- “Breathing zone” -- distance from floor of air intake -- is lower, may lead to inhalation of air of different quality from the adult
- The attractive hazard

http://www.home-air-purifier-expert.com/images/hazardous-chemicals.jpg

Differences in intake





- Higher metabolic rate = more food intake per kg of body weight
- Young children eat 16x more apples than adults, per kg; 3x more potatoes, per kg; etc
- Therefore, pesticide residues normally found on apples would be expected to make a larger impact on the young child

Heavy Metals as Childhood Toxins

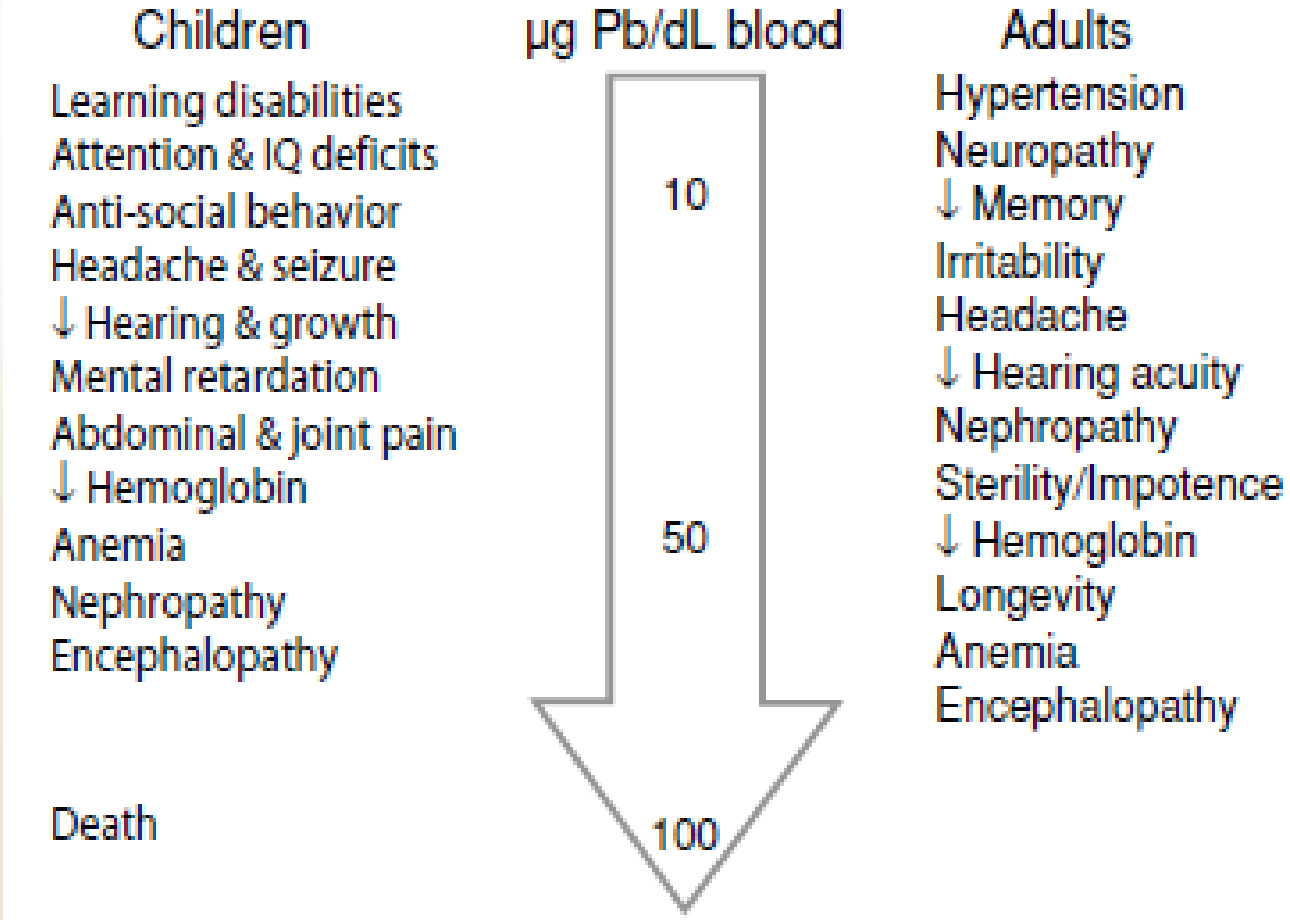
- Lead
  - Brain damage at high levels (> 80 μg/dL)
  - Anemia at blood lead (BLL) > 5 μg/dL
  - Intellectual impact on children at low levels
  - No clearly defined safe level
  - US Advisory Committee on Childhood Lead Poisoning Prevention recommends intervening at BLL >5 μg/dL

Lead effects

- Lead effects are observed on an average, population basis
- Lead effects difficult to ascertain or attribute at the individual level

Adverse effects of lead

FIGURE 1. Effects of lead poisoning on human health[a]



From Olympio et al.
Pan Am J Public Health
2009; 26(3): 267.

Monitoring for lead toxicity

- Required surveillance of young children
  - At ages 1-6 yr, testing or questionnaire-based surveillance
  - Depends on risk assessment
- Also for industrial exposures of adults
- Required reporting of BLL
  - In GA, all BLL results are required reports to state DPH

Monitoring for lead toxicity - 2

- Comparison between expected BLL and those reported
- Shows many expected samples are missing
- Under-reporting or under-sampling?
- Under-sampling due to skipped health care visits or failure to sample at visits that do occur?
- 2017 publication of 1999-2010 data stated that GA "ascertainment success" in only 10% of expected, versus 39-state average of 64%

Roberts EM et al. Pediatr 2017; 139: e20164266

Historical Blood Lead Levels

TABLE IV-1. Blood Lead Levels Of Children in the United States 1976-80 (percent in each cell; rows sum to 100 percent)

	<10 ug/dl	10-19 ug/dl	20-29 ug/dl	30-39 ug/dl	40-69 ug/dl
All Races					
all ages	22.1	62.9	13.0	1.6	0.3
6 months-5 years	12.2	63.3	20.5	3.5	0.4
6-17 years	27.6	64.8	7.1	0.5	0.0
White					
all ages	23.3	62.8	12.2	1.5	0.3
6 months-5 years	14.5	67.5	16.1	1.8	0.2
6-17 years	30.4	63.4	5.8	0.4	0.0
Black					
all ages	4.0	59.6	31.0	4.1	1.3
6 months-5 years	2.7	48.8	35.1	11.1	2.4
6-17 years	8.0	69.9	21.1	1.0	0.0

Source : Table 1, Advance Data #79, May 12, 1982, from Vital and Health Statistics, National Center for Health Statistics (Supplemental Exhibit 4.) NOTE : These results were produced after adjusting the data for age, race, sex, income, degree of urbanization, probability of selection, and non-response to the NHANES survey.

From Schwartz J. Costs and Benefits of Reducing Lead in Gasoline. EPA, 1985

Lead Sources in the Environment

- Leaded gasoline
  - Initial concern raised in 1920's about lead addition to gasoline, but lead only removed in late 1970's in US
- Lead paint – limited use in US since 1973
- Crafts
- Automotive
- Plumbing
  - Further restricted since 2001

Current Lead Sources

- Peeling paint in buildings built before 1973
  - Schools, day care, homes, public buildings
  - Particularly those less well maintained
  - Effects even well maintained buildings where the leaded layer is exposed to the surface
- Water
  - Old service lines
  - Old plumbing fixtures
    - Older water coolers a particular issue
- Imported inexpensive toys and jewelry
  - May contain excessive amounts of lead

Lead

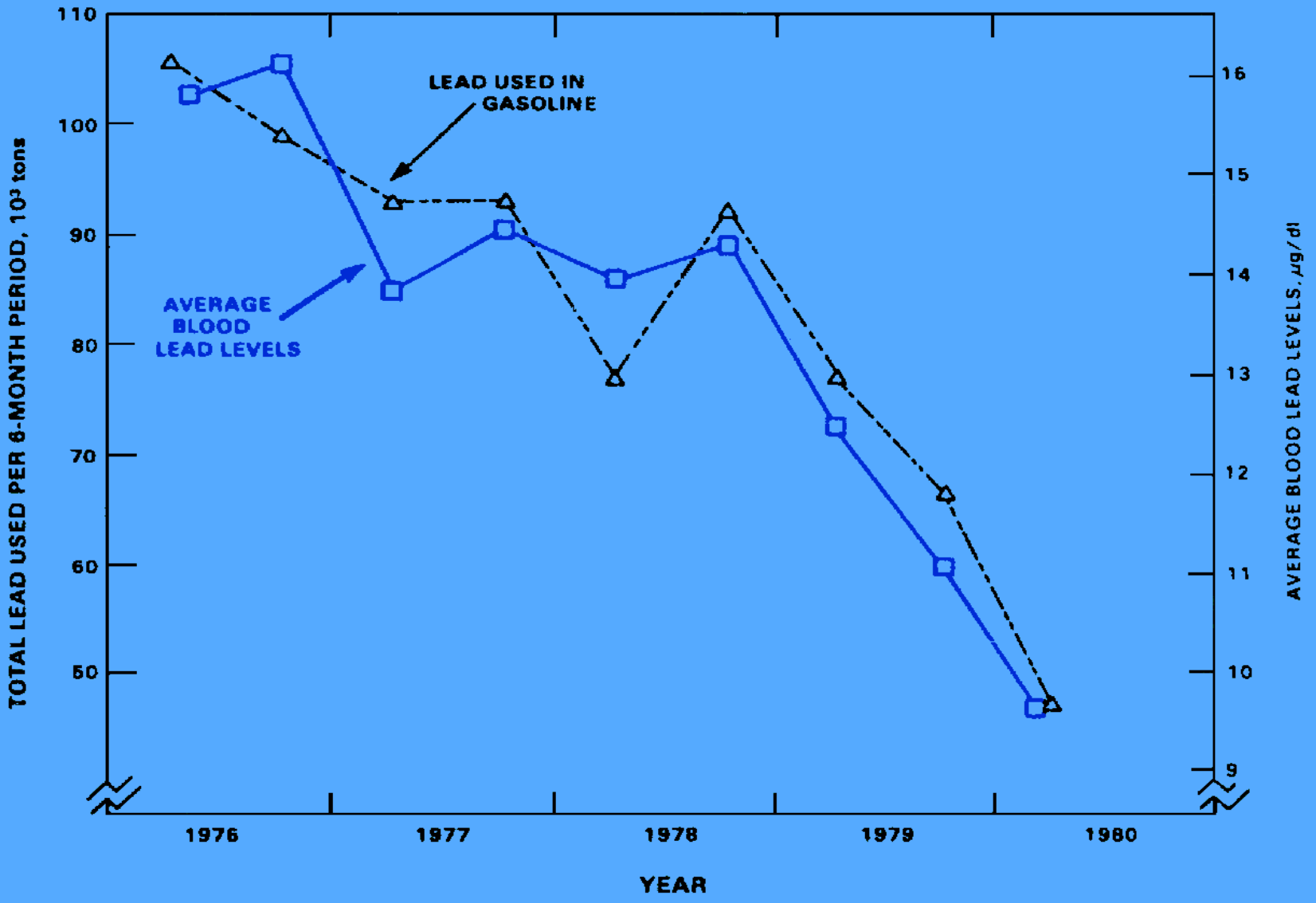


Figure VIII-1. Parallel decreases in blood lead values observed in the NHANES II Study and amounts of lead used in gasoline during 1976-1980.

Source: Annest et al. (1983).

Measuring body burden of lead

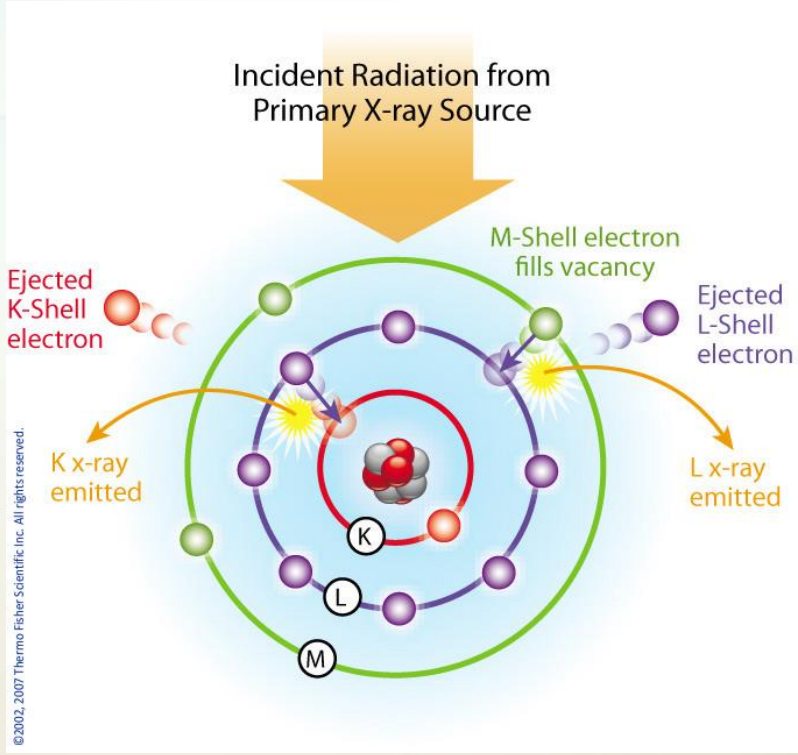
- The gold standard is blood lead level
- Requires minimal amount of blood
- Collection via fingerstick or phlebotomy
  - Fingerstick- possibility of falsely elevated result
  - Venous- historical gold standard

Analytical concerns

- Lead Care systems
  - Mainly used in point of care testing
  - Concerns about missing low to moderate elevated results
  - Recommendation to only use central lab methods such as AAS
- Atomic Absorption Spectrophotometry (AAS)
  - Currently the gold standard

Lead Poisoning- Other Diagnostic Methods

- Xray Fluorescence (XRF)
  - XRF interprets spectral emissions of various elements after they are bombarded by Xrays
- Currently FDA unapproved for measuring lead in people
- Gold standard for environmental measurement



Courtesy Niton Corp., at http://www.niton.com/portable-XRF-technology/how-xrf-works.aspx?sflang=en

X-Ray Fluorescence Use

- Often used in human research studies

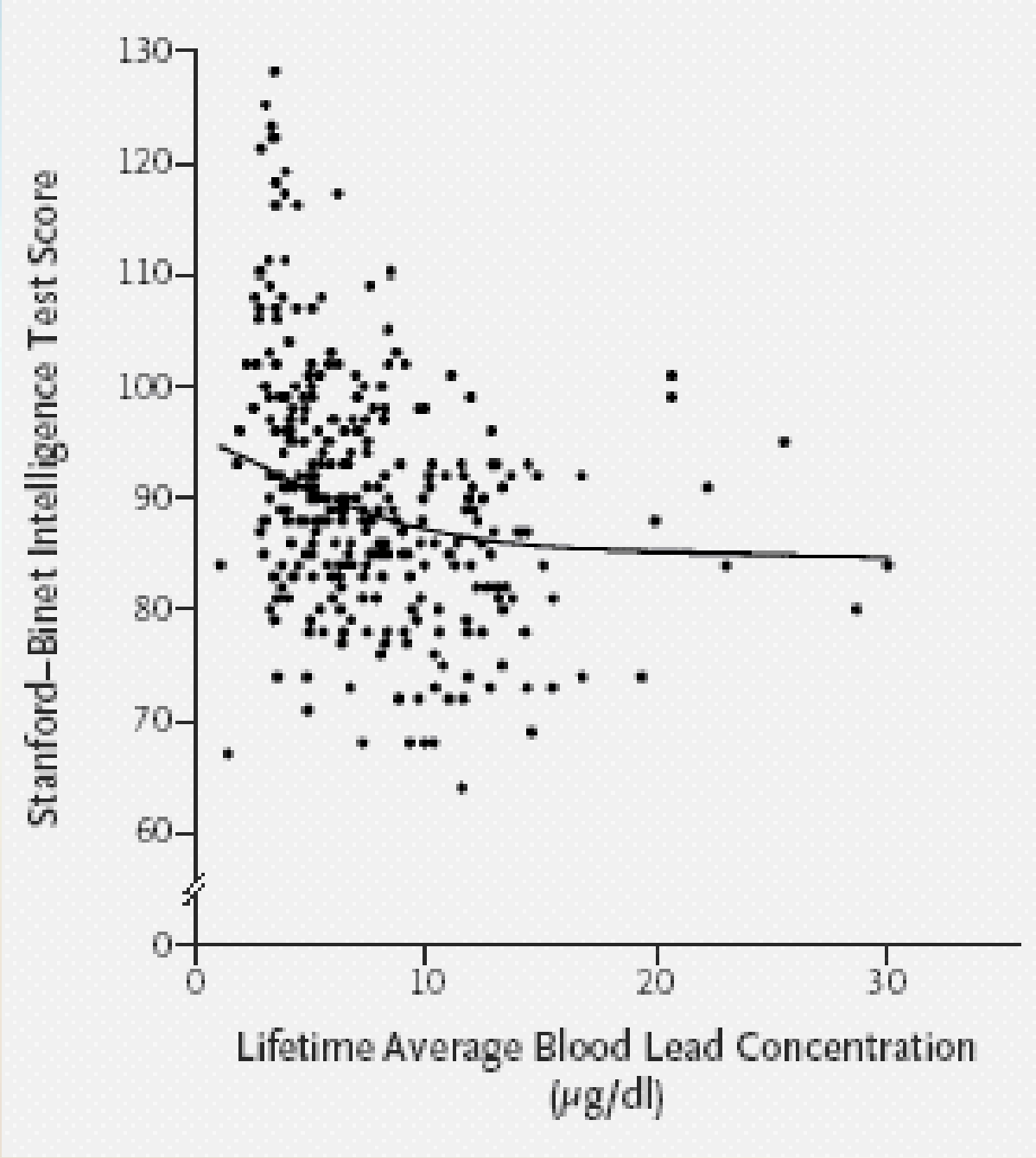
Device image courtesy of http://www.niton.com/Niton-Analyzers-Products/xltpi.aspx?sflang=en

Lead and IQ

- No clearly established threshold for lead toxicity
- Extent of *mean* IQ reduction:
  - ≈ 0.25 IQ points per μg/dL BLL at BLL <5 μg/dL
    (Landrigan P et al. Environ Health Perspect 2002; 110:721-728)
  - 3.9 IQ points more from BLL increasing 5-> 20 μg/dL
  - 3.5 IQ points more from BLL > 20 μg/dL
    (Fewtrell LJ et al. Environ Res 2004; 94: 120–133)
- "Normal" BLL calculated to be <0.1 μg/dL

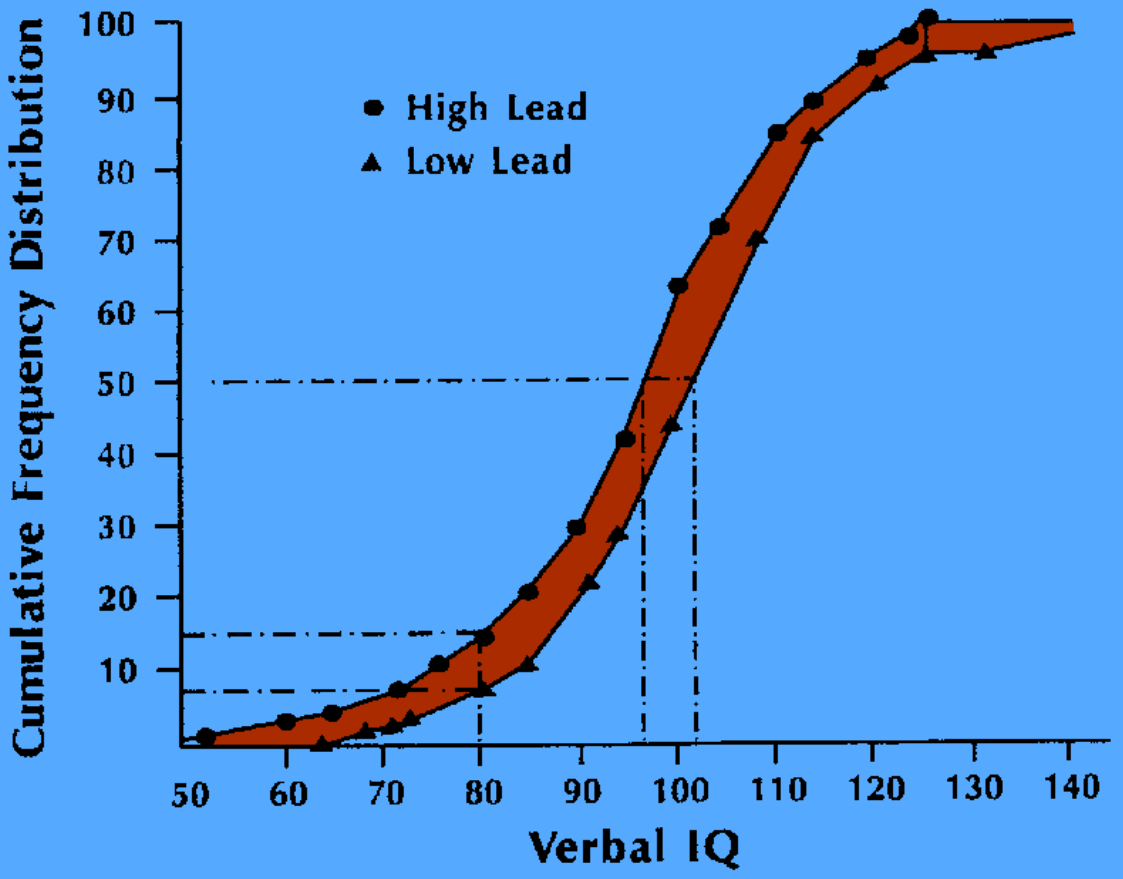
Lead Impact on IQ

Canfield et al
NEJM 2003; 248: 1517-1526



Lead's impact on verbal IQ

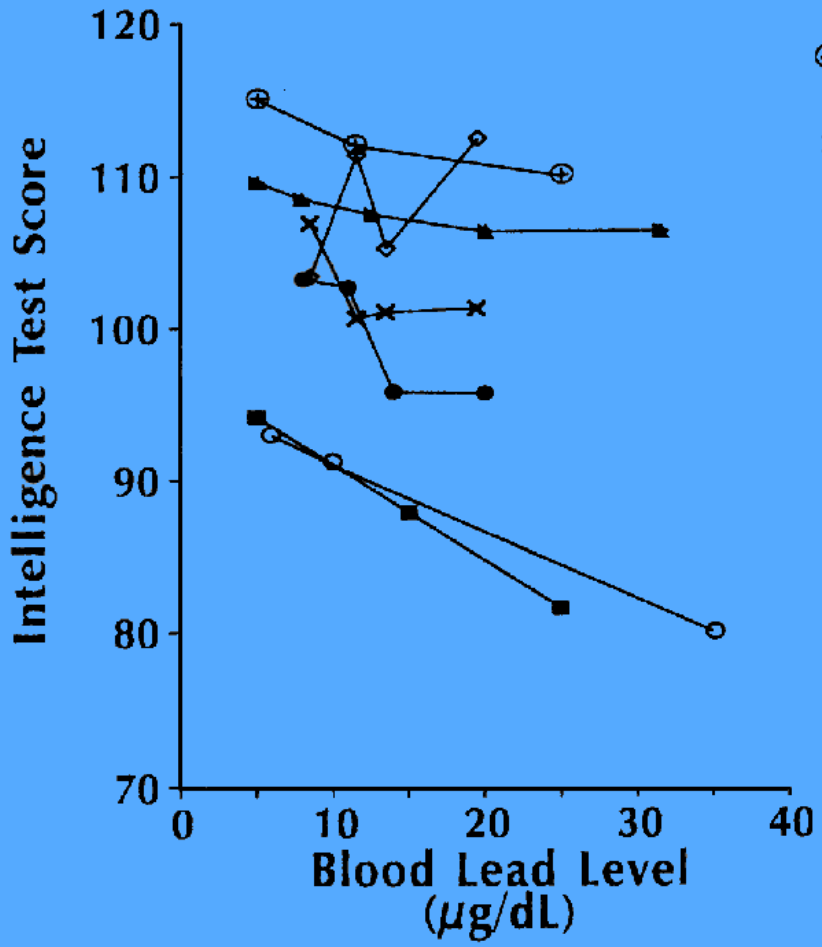
Cumulative frequency distribution of verbal IQ scores in children with high and low tooth lead levels



Source: Needleman et al., 1979.

Lead blood levels vs. IQ

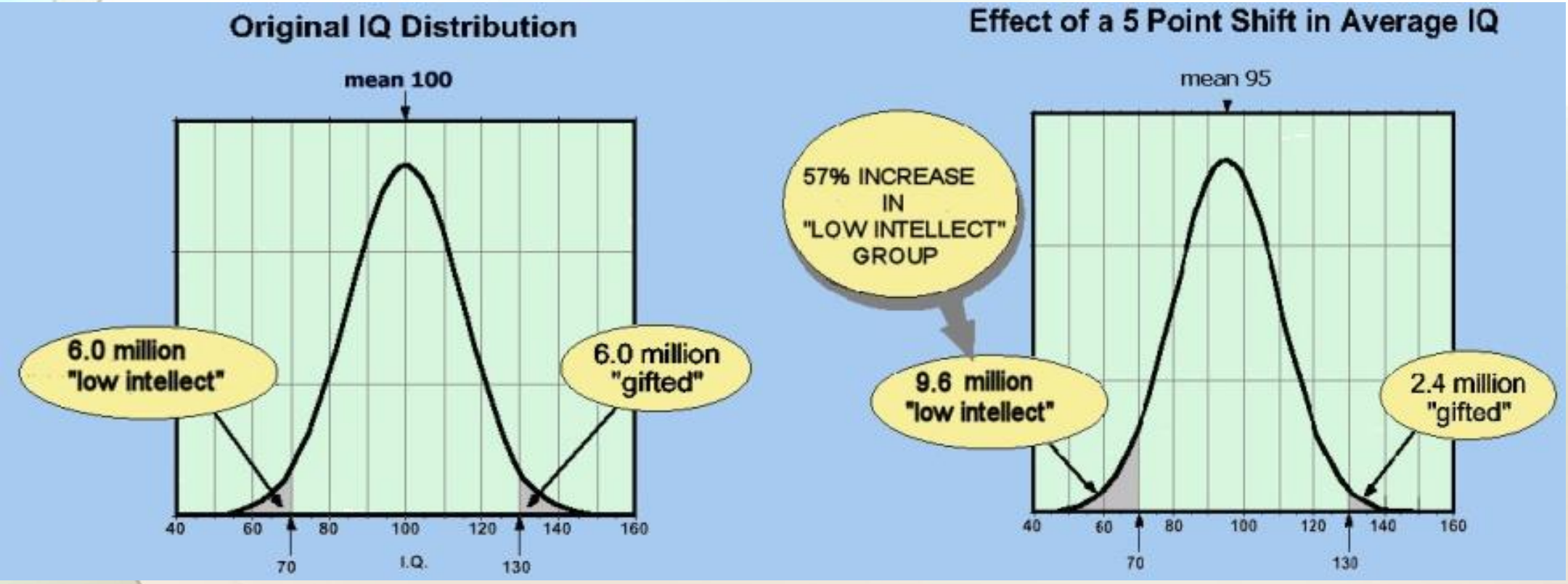
Blood lead levels and IQ scores of children, from cross-sectional and retrospective cohort studies*



- ⊕ Fulton et al. (1987)
- ◣ WHO/CEC (Winneke et al., 1990)
- × Lansdown et al. (1986), manual occupation
- ◇ Lansdown et al. (1986), non-manual occupation
- ● Yule et al. (1981)
- ■ Schroeder et al. (1985)
- ○ Hawk et al. (1986)

*Data from prospective studies are not included.

Result of a 5 point reduction in average IQ



Lead and Behavior

- ADHD
- Disruptive behavior

Lead and ADHD

TABLE 3. Simple Comparisons of Behavior Rating Scale Total and Factor Scores by Lead Group*

	Exposed† (n = 41)	Nonexposed‡ (n = 31)	P§
BRS total score (percentile)	46.9 (29.5)	62.7 (26.1)	.02
Emotional Regulation Factor	40.8 (29.5)	55.4 (29.8)	.04
Orientation Engagement Factor	45.1 (33.8)	59.2 (27.9)	.06
Motor Factor	91.3 (19.8)	93.0 (18.0)	.71

* Data are presented as mean (SD).
† Lead level between 0.48 and 1.20 μmol/L (10 and 24.9 μg/dL).
‡ Lead level between 0 and 0.48 μmol/L (0 and 9.9 μg/dL).
§ *P* value based on *t* test.

Mendelsohn AL, et al. Pediatr 1998;101:e10

Lead and Behavior

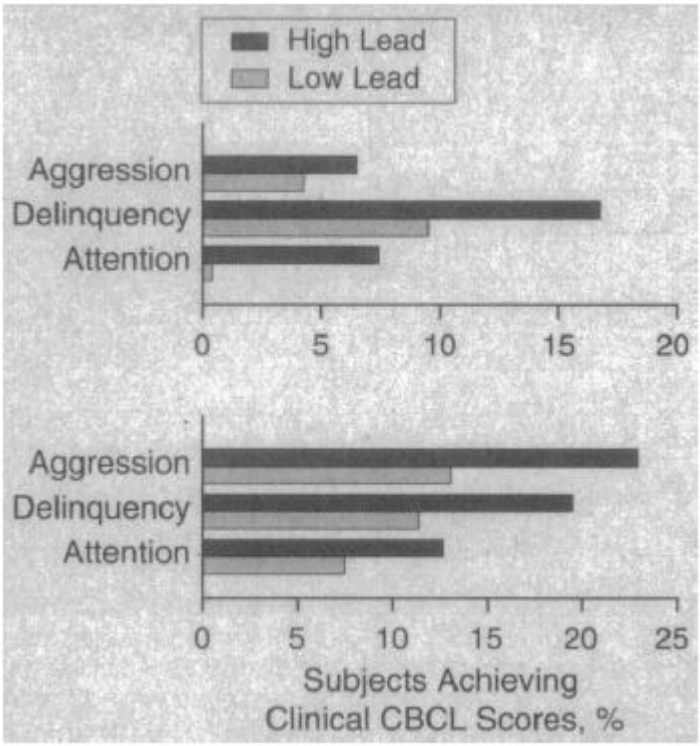


Figure 4.—The association between bone lead concentation and clinical Child Behavior Checklist (CBCL) (T>70) scores for aggression, delinquency, and attention. Subjects are classified as "high lead" (above the median) and "low lead" (below the median). Both parents' CBCL scores (top) and teachers' scores (bottom) are displayed.

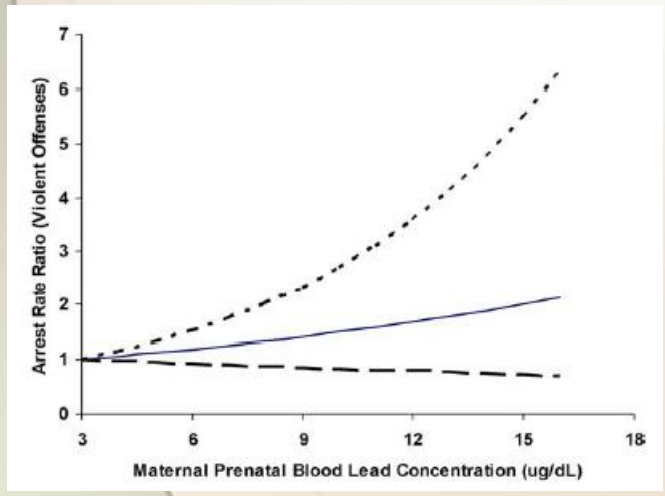
Needleman HL et al. JAMA. 1996;275:363-369

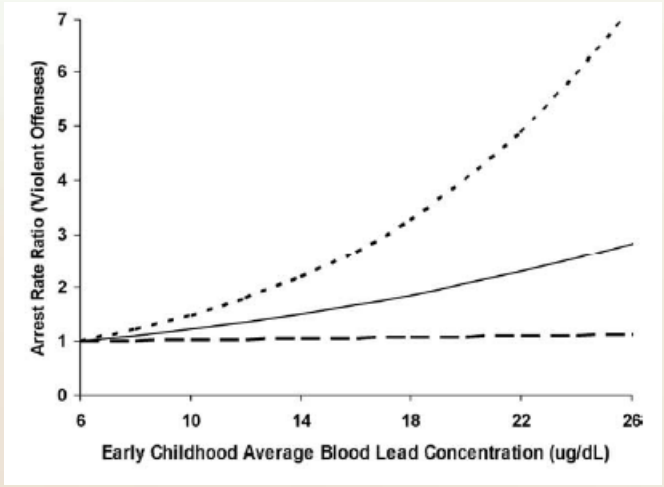
Lead Effect on Violent Crime

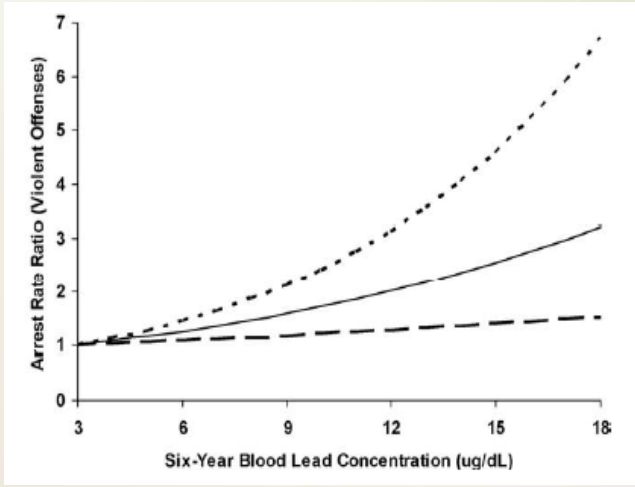
Table 3. Relationship of Prenatal, Early Childhood Average, and Six-Year Blood Lead Concentrations with Violent Crime Arrest Rates in Young Adults

Blood Lead Variable	Median (5th–95th Percentile), µg/dl[a]	Attributable Risk (95% CI), per Year	Rate Ratio for 5 µg/dl Increase in Blood Lead (95% CI)
Prenatal	7.8 (2.9–16.0)	0.055 (0.026–0.118)	1.34 (0.88–2.03)
Early Childhood Average	12.3 (6.0–26.3)	0.077 (0.039–0.156)	1.30 (1.03–1.64)
Six-Year	6.8 (3.4–18.3)	0.087 (0.049–0.152)	1.48 (1.15–1.89)

Estimates adjusted for maternal IQ, sex, SES using the Hollingshead Score, and maternal education level.







Wright JP et al. PLoS Medicine 2008; 5 (#5): 0732- 0740.

Other risk factors

- Genetic variability
  - Some gene polymorphisms in lead transporting or lead elimination proteins are associated with larger impact of lead on learning at similar BLL
  - Parental IQ
- Social factors
  - Disadvantaged setting

Which children are at high risk from lead?

- Children in homes built using leaded paint (US: 1920's - early 1960's), particularly while being renovated
- Children whose parents work in lead industries
- Children of parents with lead poisoning
- Children whose siblings have high lead
- Children adopted from countries with lower environmental standards

Lead Poisoning Prevention - US

- Prevent exposure, particularly in early childhood
- Reduce avoidable release into the environment and the workplace
- Early detection at the mild stage

Lead Poisoning – What to Do?

- Terminate exposure to further lead
- Abate housing
  - Lead paint
  - Lead plumbing
  - Renovate safely
- Avoid leaded pottery for cooking / eating
- Avoid ethnic remedies that contain lead

Lead Poisoning Interventions

- Prevention is cost effective
  - Remediate lead-contaminated dwellings
  - Abate contaminated sites
    - “Chat piles”
    - Metal smelting sites
    - The case of Herculaneum and surrounding communities in Missouri

Interventions for the Individual

- Supportive care
  - Early intervention programs have been proven to mitigate lead-driven disabilities
- Symptom- based monitoring and treatment
  - Hypertension, for example
- Chelation as a last resort
  - Expensive
  - Not demonstrated to change the IQ or behavioral impact

Natural History of Human Lead Body Burden

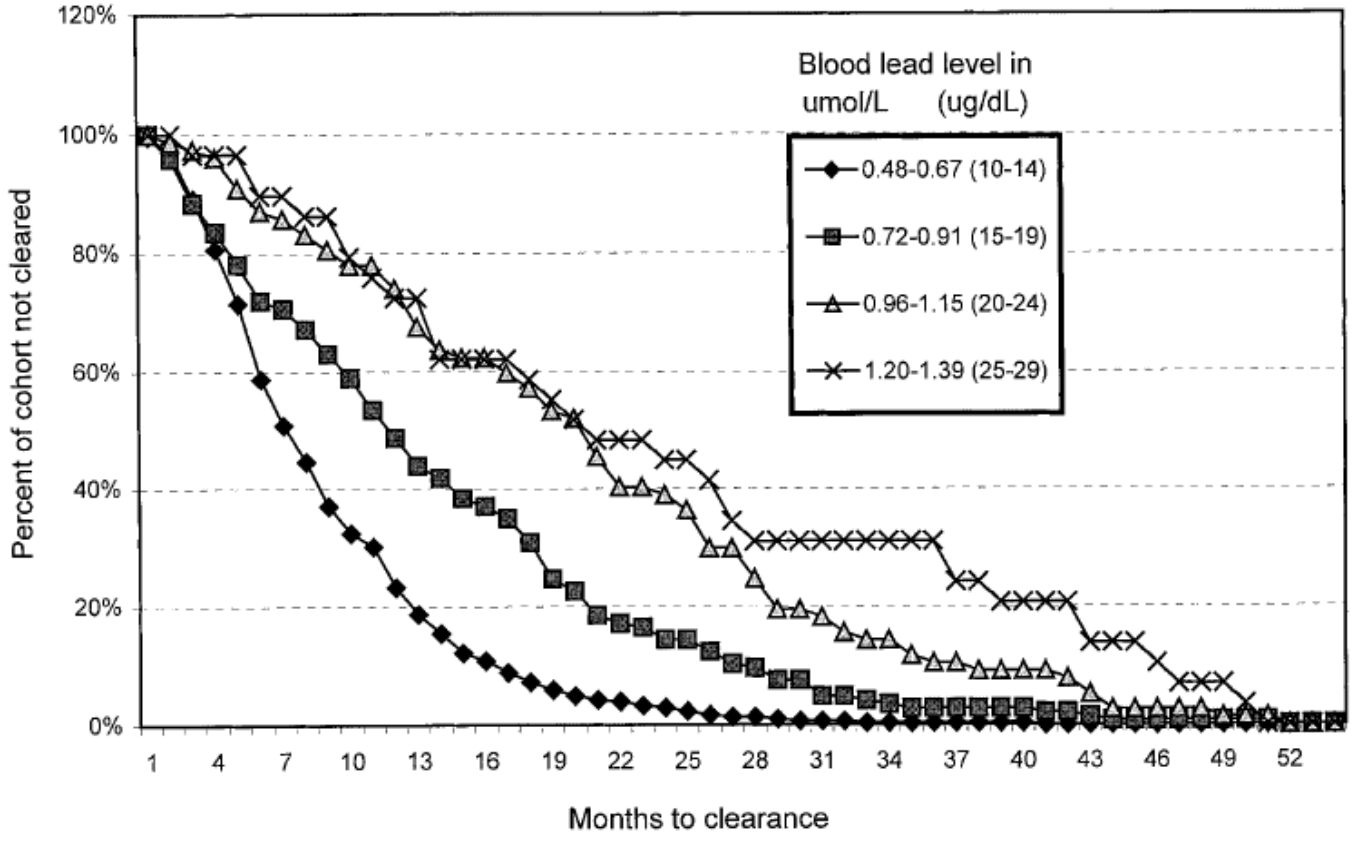


Figure 2. Kaplan-Meier survival analysis showing the percentage of cohort categorized by lead level cleared over time in months.

Roberts JR et al. Clin Toxicol 2001; 39: 153-160.

Some interventions that may be useful

- Assess built environment of every child with BLL confirmed to be greater than CDC action level
  - Currently 5 μg/dL
- Extend BLL monitoring to pregnant women
- Extend BLL monitoring to women of childbearing age *before* they become pregnant
  - Cannot treat lead poisoning during pregnancy
- Subsidize remediation of structures found to be the source of childhood lead poisoning
- Facilitate more complete BLL monitoring of children under 3 years of age

Risk communication is essential

- Information provided to the public must be accurate and clear
- Easy to lose credibility, very hard to get it back
  - Exaggerating the data leads to bad policy and public distrust
  - Essential to have skilled presentations to public and professional groups
  - Try to build consensus before going public

What happened in Flint, MI

- To save money, the state and city switched the water supply from Detroit municipal system to the Flint River in April 2014
- Stopped adding orthophosphates (which reduce leaching of lead from pipes)
- Multiple community concerns about water quality ensued – including bacterial counts, minerals, etc

The 2016 data from Flint MI

Methods. We reviewed blood lead levels for children younger than 5 years before (2013) and after (2015) water source change in Greater Flint, Michigan. We assessed the percentage of elevated blood lead levels in both time periods, and identified geographical locations through spatial analysis.

Results. Incidence of elevated blood lead levels increased from 2.4% to 4.9% ($P < .05$) after water source change, and neighborhoods with the highest water lead levels experienced a 6.6% increase. No significant change was seen outside the city. Geospatial analysis identified disadvantaged neighborhoods as having the greatest elevated blood lead level increases and informed response prioritization during the now-declared public health emergency.

- Hanna-Attisha M, LaChance J, Sadler RC, Schnepp AC. Am J Publ Hlth 2016; 106_283-290.

Flint: Poisoned drinking water causing irreparable brain damage - BBC News

Quora

Who is criminally responsible for the lead poisoned permanently brain damaged children of Flint Michigan?

Thousands of innocent children have been permanently disabled for life. There is no safe level of lead as any amount of lead is Lead poisoning which can cause irreversible brain damage. How Flint's Water Got Poisonous

How The Flint Water Crisis Could Send An Entire Generation To Prison

BY CARIMAH TOWNES JAN 22, 2016 10:58 AM

Flint mayor declares 'manmade disaster' over lead-tainted water supply

The Michigan city has declared a state of emergency over contaminated water, affecting the entire city of 100,000 residents and those who commute there

Employees at the Flint, Michigan General Motors plant, which stopped using Flint water because it was rusting the machinery. Photograph: Jake May/AP

Flint Mayor declares state of emergency

Office of Mayor Karen W. Weaver, Ph.D.
City of Flint, Michigan, County of Genesee

Declaration of State of Emergency

Authority Emergency Management Act: Michigan Emergency Management Act 390 of 1976

BY THE MAYOR:

Whereas; in accordance with the Michigan Emergency Management Act, I am declaring a State of Emergency for the incorporated boundaries of the City of Flint, Michigan; and

Whereas; the City of Flint has experienced a Manmade disaster by switching to the use of the Flint River before connecting to KWA; and

Whereas; the City of Flint children have experienced increased blood lead levels since the switch to the Flint River; and

Revisiting Flint, as compared to all of Michigan

In 2005, Michigan completed the years-long process of collecting 500,000 lead blood tests from children in the state under 6. Back then, 26% of kids tested — that's more than one in four — had blood lead levels (5 micrograms per deciliter or greater) that would cause concern today. In the hardest hit parts of Flint now, only 10.6% of kids have such concerning levels of lead in their blood.

David Mastio in USA Today 2016-1-22, citing
http://www.oem.msu.edu/userfiles/file/Annual%20Reports/Lead/05Lead_all.pdf

Flint is not alone…

- Sebring, OH - 2016
- Washington DC, 2001
  - change in water disinfection practices resulted in tap water lead >US standards as much as 20-fold
  - Pipe replacement over 3 years only partially solved the problem
- Philadelphia - ongoing
- Columbia, SC 2005
- Durham and Greenville NC, 2006

Lead service lines

- Widespread
- Expensive and intrusive to fix
- May affect up to 70% of municipal water systems in the US

And about lead in water

- We should not have elevated lead in water
- This is a problem that affects many, too many communities
- We can help now where this is a problem
  - Install a water filter that removes lead from the water for all water used for cooking and drinking

Questions?

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